EVALUATION OF CAD/CAM GENERATED CERAMIC POST & CORE

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Evaluation of CAD/CAM generated ceramic Post & Core

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Objective

The purpose of this study was to evaluate the use of CAD/CAM technology as a method to fabricate a single-unit, all-ceramic Post & Core restoration.

Materials and Methods

Three master dies were fabricated from polymer material (Acadental T Endo TM series RT _AE401_08 ®). The coronal part of the die simulated an ideal core preparation with a 1.5 to 2mm ferrule. The intracanal space of the first die was prepared for a post length of 5mm. The intracanal space for the second die was prepared for a post length of 10mm. Finally, the intracanal space for the third die was prepared to a length of 14mm. Each die was scanned 20 times using the Sirona CEREC AC BlueCam®. A total of sixty e.max® CAD/CAM post and core restorations were milled using Sirona CEREC three compact milling unit®. The restorations were evaluated for precision of fit using 2 methods:

1. The marginal gap was measured for each Post & Core restoration using scanning electron microscopy to determine the accuracy of fit of the core to the die. Measurements were made at three points: mesial, buccal and distal of each sample. The mean marginal gap for the three groups was 38 um.

2. A radiograph was taken of each of the 60 samples to determine the post length. The mean post length for the group that was calibrated for 5mm was 6.3mm. Mean post length for the group that was calibrated for 10mm was 10.0mm. Mean post length for the group that was calibrated for 14mm was 11.0mm. Overall, there was no pattern of relationship between marginal gap and post length among the three groups.

Conclusion

This study concluded that the focal working length of Sirona CEREC AC® BlueCam is accurate up to 13.7mm. However, the technology is not able to consistently produce accurate milled post and core restorations beyond 11mm. The mean marginal gap for the three groups was 38 um. Future studies are needed to evaluate the biomechanical properties of ceramic Post & Core restorations.

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1.0 INTRODUCTION

Endodontically treated teeth show greater risk of failure than their vital counterparts. In the case of insufficient tooth structure those teeth often need a Post & Core as a foundation for the final restoration. A Post & Core protects the remaining tooth structure and allows the restoration of function[1].

Post & Core restorations were first introduced to dentistry by the father of modern dentistry, Pierre Fauchard, in the form of gold and silver posts during the 18th century. They enabled replacement of missing tooth crowns with porcelain crowns[2]. The first combined Post & Core with a porcelain facing was introduced to dentistry by an American dentist “C. M. Richmond” (1835–1902) and was termed the Richmond crown[3].

Post & Core restorations are classified into two main categories: Custom made and Prefabricated. A cast metal Post & Core is traditionally the treatment of choice to provide the necessary retention and strength for a final restoration. It is custom fit to the prepared post space. This can be achieved through an indirect impression of the prepared canal using an elastic impression material, or through a direct pattern technique[4]. The restoration of endodontically treated anterior teeth using cast metal Post & Core underlying all ceramic crowns usually results in a poor esthetic outcome due to the translucency of ceramics[5]. A cast metal Post & Core can usually be used in cases where the crown thickness is more than 1.6mm[6]. However, according to

Nakamura, et al, a single unit zirconia Post & Core is recommended in cases where the ceramic crown thickness is under 1.6mm[7].

Prefabricated glass fiber posts have variable shades, enhanced mechanical properties and better biocompatibility[8,9]. Their main disadvantage is that their diameters cannot be customized to adapt to individual post space preparations. Custom made Posts & Core is indicated in cases with wide, noncircular, or extremely tapered canals where cylindrical prefabricated posts may not achieve adequate adaptation of the post to the canal[10,11]. The weak interface between the resin core and the fiber post may also increase the risk of failure[12]. According to a 10-year retrospective study by Balkenhol, et al., the fit of a cast Post & Core directly influences the ultimate survival of the restoration[13].

The long-term failure rate of fiber posts reportedly ranges from 7 to 11%[9,14]. Apart from endodontic problems the primary reasons for failure include crown dislodgement and post debonding. Assif and Gorfil[15] reported that endodontically treated teeth restored with Post & Core restorations can produce stresses concentrated at the coronal third of the root and at the interface between the core and the post. If the modulus of elasticity differs between materials, there is potential for separation of the core from the post. Such separation is less likely to occur when the post and the core are composed of the same material[16].

A new method of fabricating custom made Post & Core is the use of monoblock zirconia and all ceramic CAD/CAM technology (computer-aided design/computer-aided manufacturing). The Post & Core restoration is generated by means of a direct optical impression of the post space or an indirect impression of a resin pattern or polyvinylsiloxane impression of the post space[4]. High-strength ceramics allow fabrication of restorations with optimal esthetics, good biocompatibility, excellent periodontal tissue response, as well as the necessary mechanical properties to withstand functional stressors. In 1992 Bex, et al.,[17] investigated the effect of dentin-bonded resin post-core restorations on the resistance to vertical root fracture and concluded that dentin-bonded resin post-core restorations provided significantly less resistance to failure than cemented custom cast Posts & Cores. In every instance the dentin-bonded resin Posts & Core fractured before the roots fractured. In 1996 Saupe, et al.,[18] compared the fracture resistance between custom metal cast Posts & Core and a resin-reinforced dowel system for structurally compromised roots. Their results indicated that resistance to masticatory load of a resin-reinforced Post & Core system was greater than that of a morphologic Post & Core restoration. They also reported that when a bonded resin Post & Core was used on structurally weakened roots there was no statistically significant difference in strength between Post & Core restorations that used a ferrule and those that did not.

Fabricating the Post & Core as a single unit decreases the frequency of failure, which offers advantages over multiple unit Post & Cores. Fasbinder et al.,[19] found that the use of digital impressions was more efficient than the traditional time involved in making impressions and pouring casts. One recent study reported that scanning was 10 minutes faster than conventional impressions for single abutments and short span fixed partial dentures[19,20]. Multiple studies have shown increased restoration quality and marginal fit with CAD-CAM systems. Another noteworthy study[24,19] examined over 1000 crowns made with polyvinyl-siloxane impressions. After 5 years of clinical service they reported that a marginal gap of less than 120 microns is clinically acceptable for cemented restorations. Digital systems have been reported to fabricate restorations with marginal fit with less marginal gap than this standard. One laboratory study[21] measured the fit of CEREC® crowns compared with those fabricated using conventional laboratory techniques. There was no significant difference in crown margin fit between the chair side CAD/CAM and the laboratory fabricated techniques. The CEREC crowns had a mean margin gap of 65.5 ± 24.7 microns for ceramic crowns and 66.0 ± 14.1 microns for composite crowns[21, 19]. An in vitro study compared the accuracy of full ceramic crowns obtained from intraoral scans using Lava COS®, CEREC AC®, and iTero® systems with two different conventional impression techniques. The mean margin fit of the crowns was 48 microns for Lava COS®, 30 microns for CEREC AC®, 41 microns for iTero®, 33 microns for single-step putty wash technique and 60 microns for the two-step putty wash technique[22]. The mean internal fit was 29 microns for Lava COS®, 88 microns for CEREC AC®, 50 microns for iTero®, 36 microns for single-step putty wash technique, and 35 for two-step putty wash technique. There was no significant difference in the margin fit or internal adaptation of the crowns using any of the previously mentioned techniques.

2.0 RESEARCH OBJECTIVES

This study evaluated the use of chair side, CAD/CAM technology as a method to fabricate single-unit all-ceramic Post & Core restoration utilizing a direct optoelectronic scanning impression of the post space [150,151].

3.0 RESEARCH HYPOTHESIS

3.1 Null hypothesis

Chair side CAD/CAM technology (Sirona CEREC BlueCam®) cannot produce direct single unit all ceramic Post & Core restorations with a canal depth of 10mm.

3.2 Alternative hypothesis

Chair side CAD/CAM technology (Sirona CEREC BlueCam®) can produce direct single unit all ceramic Post & Core restoration up to 10mm of intracanal depth.

4.0 REVIEW OF LITERATURE

The purpose of the post is to retain a core needed to support a crown restoration due to the extensive loss of tooth structure. Preparation of a post space should be relevant to that need. Multiple guidelines for post length can be found in literature: the post length should equal the incisocervical or occlusocervical dimension of the crown[25,26,27,28,29,30,31,32]; the post should be longer than the crown[33]; the post should be one and one-third of the crown length[34]; the post should be one-half of the root length[35,36]; the post should be two-thirds of the root length[37,38,39,40,41]; the post should be four-fifths of the root length[42]; The post should be terminated halfway between the crestal bone and root apex[43,44,45]; the post should be as long as possible without disturbing the apical seal[46].

According to current endodontic textbooks[47] about 4mm of gutta-percha is needed to provide an appropriate apical seal. Because of variation in the angulation of radiograph, it is prudent to leave 5mm or more gutta percha as it appears on a radiograph[47,48,49]. For the anterior and bicuspid teeth the recommendation is for 5mm of apical gutta-percha, and that the post should extend to that level. The recommendation for molar teeth is determined by the potential for root perforation. Posts in molars should be extended only 5mm into the canal length[47,50]. After measuring 700 teeth Shillingburg, et al., noted that making the post length equal to the clinical crown length causes the post in some teeth to encroach on the 4mm "safety zone"[51]. Zillich and Corcoran presented data comparing length guidelines to average, long, and short root lengths and the need to retain adequate apical seal. When posts were one-half of the root length the endodontic seal of 5mm was rarely compromised on average roots. When posts were two-thirds of the root length many of the average and short root length teeth had compromised apical seals. When posts were equal to the crown length an adequate seal was only possible on teeth with average or long root lengths. With short-rooted teeth even the shorter post guideline of being equal to the crown length produced a compromised apical seal. They did not calculate data for posts as long as three-fourths of the root length[61]. A second criterion in the post preparation is post diameter. It should not be more than one third of the root diameter and should be minimally apical[52,53.].

Another key guideline in post development is the ferrule. It amounts to a circumferential band of metal that wraps the tooth structure, and is the key element preventing future tooth fracture. The crown ferrule ideally should cover more than 1mm of tooth structure[54]. A ferrule that engages 2mm of tooth structure around the entire circumference provides greater fracture resistance[55,56].

Post & core restorations are classified into two broad categories: Custom made and prefabricated. Cast metal Post & Core is custom made and is traditionally the treatment of choice to provide the necessary retention for a final restoration. It is designed to provide a custom fit to the prepared post space. Other attributes of cast Post & Core restorations are high durability, strength and the strong monoblock union between the core and the post. However, they have been associated with deep root fracture due to their higher modulus of elasticity than dentin[57]. The fiber reinforced Post & Core restorations offers improved esthetics and more favorable stress distribution[58]. Overall, the cast Post & Core is still superior in situations where teeth have suffered extensive damage, serve as an abutment for fixed partial denture, or in bruxism situations. Cast Post & Core restorations can be fabricated indirectly by means of an impression of the prepared canal using an elastic impression material or directly via a resin pattern technique[4]. Another method of fabricating a custom made Post & Core is the use of CAD/CAM technology to generate the Post & Core restoration from a ceramic block[4].

Prefabricated posts made of metal, carbon or fiber reinforced allow more desirable shades and enhanced biocompatible properties. This can be attributed to their compatible modulus of elasticity to dentin and luting cements which decrease the stresses and the risk of root fracture[8,9,60]. Moreover pre-fabricated posts allow for shorter dental visits. The main disadvantage of the pre-fabricated posts is that their diameters cannot be customized to adapt to individual post space preparations which can be very wide, noncircular, or have extremely tapered canals. This can compromise retention[10,11].

A weak interface between the resin core and the fiber post may increase the risk of failure[12.] A 10-year retrospective study by Balkenhol, et al., revealed that the fit of a cast Post & Core directly influences the survival of the restoration[13].

5.0 DIGITAL DENTISTRY

Digital dentistry is a term used to describe the clinical application of Computer Assisted Design/Computer Assisted Machining (CAD/CAM)[62,63]. All CAD/CAM systems consist of three components[64]:

1. A digitalization tool/scanner that transforms geometry into digital data that can be processed by a computer.
2. Software that processes the data and produces a data set which can be used in the fabrication of a product.
3. Production hardware that transforms the data set into the desired product.

First, the patient's intraoral condition is recorded using an intraoral camera or scanning device to capture a digital file of the dentition. The software program is then used to manipulate the data and to design the desired restoration. It enables alteration of the parameters and morphology of the restoration to a desired design. After the design has been finalized, a machining device is used to mill the planned restoration. Most machining methods are subtractive. The final restoration is cut from a preformed block of restorative material in a milling chamber[63]. The first two parts of the system play roles in the CAD phase, while the third makes up the CAM phase.

CAD/CAM systems can be divided into two classifications based on their digital data sharing capacity[65]. Closed systems offer all CAD/CAM procedures, including data collection, virtual restoration design and fabrication. All steps are enclosed within the system. There is no interchangeability or exchange between different systems. Open systems allow sharing of original digital data with other CAD software and CAM devices[66]. Another classification depends on the location of the components of the CAD/CAM system. In dentistry three different production concepts are available:

1. Chairside Production-All components of the CAD/CAM system are located in the dental treatment area. Fabrication of dental restorations take place at the chair side without laboratory support.

2. Laboratory Production-The dentist sends an impression to a laboratory where a master cast is fabricated first. The remaining CAD/CAM production steps are carried out entirely at a laboratory. With the assistance of a scanner, three-dimensional data are produced from the master die. These data are processed employing dental design software. Following the CAD-process the data is sent to a special milling device that ultimately produces the restoration.

3. Centralized Production-The third option of computer-assisted production of dental prostheses is centralized production in a milling Centre. In this variation it is possible for 'satellite scanners' in the dental laboratory to be connected with a production Centre via the Internet. Data sets produced in a dental laboratory are sent to the Production Centre for the restorations to be generated by a CAD/CAM device. Finally, the production Centre sends the prosthesis to the responsible laboratory. Production steps 1, and 2 take place in the dental laboratory, while the third phase takes place at the Centre[64,67,68].

6.0 INTRA ORAL SCANNERS

There are two primary classifications of intra-oral scanners:

- Single image and video camera
- Optical scanners and mechanical scanners

Single Image and Video Camera Scanners[19].

Single image cameras record individual pictures of the dentition. The iTero®, E4D, and TRIOS® cameras are single-image cameras. The TRIOS® camera records images at such a rapid rate that it approaches a functional appearance of a video camera. Three teeth can be included in a single image. To record larger areas of the dentition, a series of overlapping individual images are registered. The software program can reassemble them into a larger three dimensional virtual model.

The Lava Chairside Oral Scanner® (COS) was the first video camera available. The True Definition Camera® is the most recent version of this video camera. The OmniCam® camera has live color streaming for video recording capability. The function of this camera is similar to any video camera where the image is recorded as the camera is moved around the dentition. The more teeth captured in the video recording, the larger is the virtual model created in the software.

Both types of computerized systems record the digital files as STL files. An important consideration is what applications are available with the proprietary. STL file is a specific proprietary system for records[70,71,72,73]

Optical Scanners and Mechanical Scanners

An optical scanner collects images of three-dimensional structures utilizing triangulation procedure. The lasers light source and the receptor unit are at a set angle to one another. A computer can calculate a three dimensional data set from the images on the receptor unit[74,75,76] . Either white light projections or a laser beam can serve as the source of illumination. The following are examples of current optical scanners:

• Lava Scan ST® (3M ESPE, white light projections)

• Everest Scan® (Kavo, white light projections)

• es1® (Etkon, laser beam).

A mechanical scanner reads the master cast line-by-line using a ruby ball and the three dimensional structure measured. The Procera Scanner® from Nobel Biocare (Göteborg) is the only available mechanical scanner. This type of scanner is distinguished by its high scanning accuracy. The diameter of the ruby ball is set to match the smallest grinder in the milling system, allowing all data collected by the system to be milled[77,78]. The data measurement technique requires complicated mechanics, which makes the apparatus very expensive and requires long processing times.

7.0 SOFTWARE

Software is created by the manufacturer to design several types of dental restorations. Available software is continually updated. The construction data is available in several formats, through mostly standard transformation language (STL) data[64,79].

8.0 PROCESSING DEVICE

CAD software data is converted into milling strips for the CAM processing. Milling devices are classified according to the number of milling axes:

3-Axis Milling Device:

A 3- axis milling device moves in x, y and z-axis. It also enables 180^0 movement. Advantages of the three axis milling device are short time milling and simplified control

[examples: InLab (Sirona)®, Lava® (3M ESPE), Cercon Brain®(DeguDent)].

4-Axis Milling Device:

In addition to the x, y and z axes, the tension bridge for a 4 axis milling device component can be turned with infinite variability [example Zeno® (Wieland-Imes)].

5-Axis Milling Devices

Adding to the three dimensional axis dimension and rotatable tension bridge (4th axis), the 5 axis milling device has the possibility of rotating the milling spindle (5th axis). These machines enable milling of complicated geometry (eg.), in the laboratory area: Ever-est Engine (Kavo®), in the production center: HSC milling device (Etkon®)[64]. Restorations milled with a

5-axial milling unit have greater accuracy than those milled with a 4-axial milling unit because 5-axial milling unit can mill undercuts in all directions [80].

8.1 Milling variant [64]

Dry processing is mostly used with zirconia oxide with a low degree of pre-sintering. Advantages include: low cost for the milling device, no moisture absorption by the Zro2 die mold which eliminates drying time before sintering. However, the low degree of pre-sintering causes higher shrinkage of the framework.

In wet milling the cutting bur is cooled by a spray of cold liquid to prevent overheating of the milled material. Wet milling is needed for all metals and glass ceramic material to prevent damage from heat. It is recommended in cases where zirconium oxide ceramic has a higher degree of pre-sintering. A high degree of pre-sintering reduces shrinkage and provides less sinter distortion [example: InLab (Sirona®), Zeno 8060(Wieland –Imes®) and Everest (Kavo®)]. Intraoral digital impression systems vary in their key features such as working principle, light source, the necessity of powder coat spraying, operative process and output file format. Systems currently available include:

1- CEREC system®

2- Lava C.O.S system®

3- iTero system®

4- E4D system®

5- TRIOS system®

8.2 CEREC System

The CEREC 1 System® (Sirona, Bensheim, Germany) was introduced in 1987. Its Duret system was the first intraoral digital impression and CAD/CAM device[81]. The concept in which the intersection of three linear light beams is concentrated on a particular point in space is known as triangulation of light[69]. Surfaces with different light dispersion decreases the accuracy of such scans. As a result the use of an opaque titanium dioxide powder coating is needed to increase scan accuracy[82].

Currently the most predominant CEREC® system is its fourth generation product, CEREC AC BlueCam®. It records images using a visible blue light emitted from an LED blue diode as its light source. The CEREC AC BlueCam® can capture one quadrant of the digital impression within 1 minute and the antagonist in a few seconds. The newest CEREC system®, CEREC AC Omnicam, was marketed in 2012. BlueCam® imaging is a single image acquisition technique. The Omnicam® imaging technology is a continuous imaging mode. It captures and generates a 3D model. The BlueCam® can be applied to a single tooth as well as a quadrant. The Omnicm® can be used for a single tooth, quadrant or an entire arch. The BlueCam® must be used with an opaque titanium dioxide powder coating before scanning to allow uniform light dispersion and to improve scan efficacy[83]. The Omnicam® allows the Powder-free scanning and precise 3D images with natural color. The powder-free ability has a distinct advantage where a larger scanning area is involved[84]. The camera tip should be held a few millimeters away from the tooth surface or should slightly touch the surface[85]. The operator is asked to slide the camera head over the teeth in a single direction to create useable data for the 3D model. Shake detection system is a new feature that can assure the 3D images are only taken when the camera is stable and still. This avoids any inaccurate data due to shaking or trembling of the operator's hand.

After scanning, the preparation is projected on the monitor and analyzed in different views. The virtual die is created and sectioned from the virtual model. The finish line is outlined by the dentist on the die. Then the CAD system biogeneric suggests an ideal restoration design to let the operator alter the proposal using some on-screen tools. Once the dentist approves the restoration, he inserts a block of ceramic or composite material of the desired shade into the CAM unit and starts the milling process. The virtual tooth image can be used to fabricate the restoration in a single visit or it can be transferred to the CEREC Connect® dental laboratory to be milled[86].

The CEREC® system is a closed system. It exports the digital data as a proprietary file that is compatible with the Sirona's supporting CAM devices such as CEREC MC®and CEREC In-Lab®. The CEREC MC® is a chair side milling unit that offers single appointment treatment. In the beginning the CEREC® chair side milling unit was not able to mill FPDs and some high strength ceramic materials. As a result, these cases had to be milled through CEREC® In-Lab. With the advancement in CEREC devices, the CEREC MC X® and CEREC MC XL® combined with CEREC AC Omnicam® can be used for most indications and materials, including FPDs and zirconium oxide[82,87].

9.0 MATERIALS FOR CAD/CAM PROCESSING

9.1 Metals

Titanium, titanium alloys and cobalt chromium alloys are available in block form for milling dental devices. Titanium is used for implant abutments and super structures. Titanium is milled under a hard wet milling process to prevent breakage or overheating of the tools.

Chromium cobalt is used for copings, framework, crowns and fixed partial dentures. It can be processed under soft dry or wet hard milling. Milling of precious metal alloys has not been popular due to the high rate of metal attrition and the high material costs. Examples: Coron®, Etkon®(non-precious metal alloy), Everest Bio T-Blank® (Kavo, pure titanium)[64,88].

9.2 Resin Materials

9.2.1 Composite Resin for Permanent Restorations

ParadigmTM MZlOO ® (3M ESPE) , introduced in 2000, is a polymer composite block based on the ZIOO composite chemistry. It relies on a proprietary processing technique to maximize the degree of cross-linking [23,89,90].

9.2.2 Composite Resin for Temporary Materials

Long term temporary crowns and bridges can be fabricated using CAD/CAM temporary blocks. The CAD/CAM process decreases polymerization shrinkage and prevents the air-inhibited layer found with chair side auto polymerizing acrylics. Vita CAD-Temp® (Vident) is a highly cross-linked, micro filled polymer that is available in variable block sizes[91]. Telio CAD® (Ivoclar Vivadent) is a millable cross-linked polymethylmethacrylate (PMMA) block intended for temporary crowns and bridges. This block is part of the Telio system that includes a self-curing composite, desensitizer, and cement[92,23].

9.3 Ceramics

Dental ceramics are classified according to their microstructure:

1. Aesthetic enamel-like ceramics with a glass content in excess of 50% exhibit properties that include high translucency and moderate flexural strength. The presence of the glass component permits the materials to be etched with hydrofluoric acid, treated with a silane coupler, and adhesively bonded to the tooth[23,93,94].

2. Polycrystalline ceramics are used to fabricate frameworks. These are made of particles exhibiting an identical crystalline structure. These relatively opaque materials are much stronger than the glass ceramics[93,94].

Table 1

Table 1.The Dental company sirona cerec- THE MOST IMPORTANT CLINICALS STUDIES 2014

AESTHETIC CERAMICS		CEREC/inLab
Feldspar		CEREC Blocs, Mark II
Glass/leucite		Empress CAD, Paradigm C
Lithium disilicate		e.max CAD LT, HT

FRAMEWORK CERAMICS		CEREC/inLab
Lithium disilicate		e.max CAD MO
$MgAl_2O_4$/lanthanum		inCeram Spinell
Al_2O_3/lanthanum		inCeram Alumina
Al_2O_3/ZrO_3/lanthanum		inCeram Zirconia
Al_2O_3 (polycrystalline)		inCoris Al, AL-Cubes
ZrO_2 Ytt		inCoris ZI, YZ-Cubes, e.max ZirCAD

CAD/CAM Glass Ceramics

CAD/CAM-Compatible Feldspathic Ceramics

CAD/CAM fabricated inlays were first processed in 1985 using a fine-grain feldspathic ceramic block (VitaTM Mark I®, Vita Zahnfabrik, Bad Sackingen, Germany)[95]. The block was fully sintered to facilitate hard machining. A 10-year prospective study reported a success rate of 90.4% of those inlays and onlays[96]. However, a much higher breakage rate of up to 36% after 2 years was also reported[97].

Vitablocs* Mark II ® (Vident, www.vident.com) was introduced in 1991. CEREC Blocs® (Sirona Dental Systems) are feldspathic glass ceramics. Both materials are fine-grained, homogeneous feldspathic porcelain with an average particle size of 4 um[98]. The small particle size allows for a high-gloss finish and minimizes abrasive wear of the opposing dentition[99]. Another example of improved mechanical properties is flexural strength that ranges from 100 MPa[100] to 160 Mpa when glazed[23,101,105].

CAD/CAM with Leucite-Reinforced Ceramics

In 1998 ProCADTM® (Ivoclar-Vivadent, Schaan, Liechtenstein) was marketed to be used with the CERECTM inLAB® (Sirona Dental Systems, Bensheim, Germany). It is a leucite-reinforced ceramic block, collateral in structure to the heat-pressed ceramic EmpressTM® (Ivoclar-Vivadent). Keshvad et al., compared its marginal gap, internal fit and fracture load with EmpressTM® and found favorable results[102]. A survival rate of 97% after three years was reported in a 5-year evaluation of clinical all-ceramic partial coverage on molars[103].

In 2006 EmpressTM CAD® (Ivoclar-Vivadent) was introduced following EmpressTM® ProCAD. It is composed of 45% leucite and possesses a finer particle size of about 1–5mm which prevents manufacturing damages[104]. Components are similar to IPS Empress® (Ivoclar-Vivadent) however the powder is first pressed into blocks and then sintered. It was developed for chair-side single unit restorations and has a flexural strength of about 160 Mpa[23,105].

CAD/CAM Milling Lithium Disilicate Reinforced Ceramics[105]

In 2006 A lithium disilicate CAD/CAM ceramic IPSTM e.max CAD® (Ivoclar-Vivadent) was brought in as a chair-side monolithic Lithium disilicate (Li2SiO5) restorative material, glasses have their flexure strength at a range from 350 Mpa to 450 Mpa. This is two to three times greater than leucite-reinforced dental ceramics[106,107]. The increased strength offers the option to either etch and adhesively bond the material to the tooth or to use a conventional cementation technique[108].

The significant increase in strength of the bonded restoration rather than a simply cemented restoration has been reported in several studies[109,110]. These blocks are fabricated by means of a pressure-casting procedure that is used in the glass industry. Shades A–D and Bleach shades are available in 3 translucencies. Blocks are provided in a pre-crystallized blue state. The blue ceramic has a flexural strength of average 130 Mpa. They contain metasilicate and lithium disilicate nuclei. After milling, re-crystallization takes place in a chair-side ceramic oven under a vacuum at 850 ^{0}for 20–25 min. After restoration tempering, lithium disilicate crystals are formed and simultaneously the ceramic is glazed. During tempering, the block changes its color to the chosen shade and translucency. During the final stage the ceramic contains 70 vol% of crystals approximately 1.5mm in size and strength increases dramatically to 360Mpa[111].

In vitro studies have reported that fracture load of e.maxTM CAD® crowns is significantly higher than that for ProCADTM and EmpressTM CAD®[112] .The material may be resistant to fatigue in cyclic loading[113]. This material is recommended for fabrication of inlays, onlays, veneers, anterior and posterior crowns, implant supported crowns and anterior bridges[114]. Few clinical studies are available for e.maxTM CAD® use. However, short-term clinical trials for single crowns have reported survival rates between 97.4% 115 and 100%,[105,116].

An in vitro study comparing lithium disilicate bridges with those fabricated with metal ceramic showed favorable results [117].

Table 2. IPS e.max ®/scientific report/vol.02/2001-2013PS /

Physical properties	Partially crystallized state	Fully crystallized state
Biaxial strength (ISO 6872)	130 ± 30 MPa	360 ± 60 MPa
Fracture toughness (SEVNB)	0.9 – 1.1 MPa $m^{1/2}$	2.0 – 2.5 MPa $m^{1/2}$
Vickers hardness	5400 ± 100 MPa	5800 ± 100 MPa
Modulus of elasticity		95 ± 5 GPa
CTE (100-500°C)		10.45 ± 0.25 $10^{-6}/K^{-1}$
Density		2.5 ± 0.1 g/cm^3
Linear shrinkage during the tempering process	0.2%	
Chemical solubility	100 – 160 $\mu g/cm^2$	30 – 50 $\mu g/cm^2$

CAD/CAM and Glass Infiltrated Alumina and Zirconia Ceramics[105]

The VitaTM InCeram® group of ceramics (InCeramTM Alumina®, Spinell, and Zirconia, Vita Zahnfabrik, Bad Sackin-gen, Germany) are slip cast, glass infiltrated ceramics that have two interpenetrating phases. The blocks are manufactured by dry pressing the ceramic powder into a mold and condensing until the microstructure has been finalized. The number of macro-pores is lower but more uniform compared to the slip-casting technique[120]. The material is then sintered and infiltrated by La-glass. After the infrastructure has been formed, veneering composite is applied for characterization. CAM InCeramTM® Spinell survival rates range from 91.7% to 100% after 5 years[118,119]. It is the most esthetic material in this category and is favored for anterior crowns. CAD/CAM InCeramTM Alumina® has been used for single anterior and posterior crowns. CAD/CAM InCeramTM Zirconia® is a glass-infiltrated zirconia (ZrO2) hardened with alumina (ZTA). It demonstrates the most strength in this category[121]. Zirconia is used for posterior crowns or bridges with one pontic due to his lack of translucency[122]. The flexural strength of CAD/CAM InCeramTM Zirconia® was reported to be acceptable for fixed partial denture (FPD) frameworks[120,105].

CAD/CAM Compatible Polycrystalline Alumina and Zirconia[105]

Polycrystalline ceramics, as alumina and zirconia, have no etchable glassy matrix. All the crystals are highly packed then sintered[123,125.] Polycrystalline ceramic is not translucent by nature and is recommended for crown and bridge copings over which veneering ceramic is recommended for favorable aesthetic outcomes[123]. Fully sintered material can be manufactured by hot isostatic pressing[126]. This method uses elevated isostatic pressure in an enclosed system in which the ceramic powder has been enveloped. The elevated pressure is maintained during the sintering process. A ceramic block is fabricated to the exact required dimensions. Milling of these blocks has been called hard machining[124].

10.0 NANOCERMICS

CAD/CAM blocks can be fabricated from the combination of nanotechnology and ceramics [eg. LavaTM Ultimate® (3M ESPE)]. Nanoceramic material advantages include ease of handling of a composite material, glaze finish, and retention similar to porcelain. LavaTM® Ultimate® (3M ESPE) contains three ceramic filler particles. Silica particles of 20 nm, zirconia particles of 4 nm to 11 nm, and assembled nanoparticles of silica and zirconia cross-linked in a polymer matrix. The material has an approximate 80% ceramic load. The flexural strength is of 200 MPa which greater than feldspathic and leucite-reinforced porcelain blocks (140 MPa to 160 MPa). Manufacturers recommended its use is for inlays, onlays and veneers[23].

11.0 REVIEW MARGINAL AND INTERNAL FIT FOR CAD/CAM GENERATED CERAMIC CROWNS

Holmes et al.,[127] described the marginal integrity as follows: "Vertical marginal discrepancy is the distance between the restoration and the preparation when measured parallel to the long axis of the abutment. Horizontal marginal discrepancy (HM) is the distance measured perpendicular to the long axis of the abutment. Absolute marginal discrepancy (AM) is the angular combination of the vertical and HM discrepancies, or the distance between the margin of the casting to the cavo surface angle of the preparation. The AM measurement is parallel to the external surface of the retainer while sitting on the abutment tooth. Internal adaptation includes axial adaptation and occlusal adaptation. All values are measured in um."

American Dental Association (ADA) specification No. 8[128] establishes that the layer of luting cement for a dental crown should not exceed 25 um if used with a type I luting cement or 40 um if a type II luting agent is employed. Although marginal openings in this range are rarely achieved, it is a clinical goal[129]. Christenson has agreed with this ADA specification[130]. Others have suggested modifying it. Fransson et al.,[131] and McLean and von Fraunhofer[132] suggested that the clinically satisfactory marginal gap after cementation should be less than 120um to 150. In addition McLean and von Fraunhofer[132] examined the marginal fit of 1000 fixed restorations over a 5-year period and found that a marginal gap less than 80 um is difficult to detect under clinical conditions. Other authors have regarded values of 100 um[135], 120 um[136] and up to 200 um[137] as acceptable. Moldovan et al.,[138] rate values of 100 um for marginal misfit as good and values of 200–300 um as acceptable. Another in vivo SEM study found that clinically acceptable margins ranged from 7 to 65 lm[146]. Other in vitro studies found values for the mean marginal gap ranging from 9 to 82 lm[139, 140, 141, 142, 143]. Mean values for restorations evaluated in vivo ranged from 77 to 190 um[144, 145].

In short, there is no conclusive evidence describing perfect fit of ceramic systems in current literature. This subject has been thoroughly researched. Marginal fit values reported are diverse and range (in um) from 7.5 to 206.3.[133,134(.)] Such variation can be attributed to lack of a satisfactory definition of "fit" along with the different methods employed to determine the fit of ceramic systems[129,133,134] .

12.0 REVIEW OF METHOD OF MEASUREMENT MARGINAL GAP

Methods Reported in Literature:

1. Direct-view technique

2. cross- sectioning technique

3. impression replica technique

4. other methods

The direct-view technique to measure gap distance is the most commonly used method to measure gap distance (47. 5%).This is followed by cross-sectioning (23.5%), and the impression replica technique (20.2%)[147]. The Direct-view technique measures the gap between the crown and die at the margin but not internally. It uses a microscope at various magnifications. This approach does not include alteration of the crown-die as sectioning or duplication of the cement layer before measuring the gap. Consequently, this technique offers a less expensive and time-consuming method. In addition, it eliminates accumulation of errors that could occur with multiple procedures. It has been reported in literature that scanning electronic microscopy (SEM) imaging is better than light microscopy to assess marginal difference of class II CAD/CAM inlays[147,148]. Groten et al.,[147,149] found no significant difference between the accuracy of the two approaches. Although according to Groten, SEM offered more appropriate and realistic observations than a light microscope, especially with complex margin morphologies.

13.0 INFLUENCE OF SAMPLE SIZE

Reliable data is critical for favorable outcomes in any research. Sample size, the number of measurements per specimen, and statistical test performed can affect the strength of statistical analysis[147,159]. Many studies using small sample sizes have reported significant standard deviations compared to the mean value, [160,161,162,163] while those using a larger sample size have produced more consistent data with lower standard deviations[164,165,166.].

The larger the number of measurements per specimen, the greater the accuracy of the analysis[167]. Individual measurements at different locations of the margin may reveal significant deviations from the mean. These may render the crowns clinically unacceptable even if the majority of the margin has an excellent fit[168]. Groten et al.,[169] examined the marginal fit of fixed dental restorations and determined that a smaller sample size can be compensated by a larger number of measurements per sample. Gonzalo et al.,[170] and Lee et al., [171] studies agreed. Both studies applied a smaller sample size (n = 10) and compensated by using a large number of measurements per sample (60 and 50 measurements) .This approach accomplished uniform distribution of data with small standard deviations compared to the mean values.

14.0 MATERIALS AND METHODS

Three master dies were fabricated from a polymer material Acadental Lenexa Kansas Real –T Endo TM series RT _AE401_08® were used. Each die was mounted in a scannable model made from Whip Mix Lean Rock stone® (Fig.1) to facilitate the optoelectronic scanning impression and make it more recognizable to the software. The die was secured in the stone model with a polyvinyl siloxane light body impression material to facilitate the seating and removal of each die. Each die consisted of a crown portion and a root portion containing a post space. The coronal part of the die simulated an ideal core preparation 2mm above the margin with a 1.5 to 2mm ferrule. Post space diameter was 2mm at the most superior point of the preparation. Canal space was prepared to three lengths according to the die group. The canal length of group A was prepared for a post length of 5mm. Group B canal space was prepared for a post length of 10 mm. Group C post space was prepared to 14mm. The ParaPost® X System (Coltène Whaledent®) drill 3, 4 and 5 were used respectively to prepare the length needed for each group. A handpiece surveyor was used to measure the preparation depth (Fig 2). The die was sprayed with CEREC Optispray® (Sirona), a light film was distributed evenly on the core and introduced to the post space using the spray nozzle. Each die, including its post area, was optoelectronically scanned using Sirona CEREC SW BlueCam® (Fig.3) and Software 4.0 edition (Figs. 4,5). A biogeneric copy was applied as a design for the generation of a similar core for all posts. A virtual model was created and the die was trimmed. Restoration parameter was set at a spacer of ten um for all groups respectively (Fig. 6). The software generated a milling proposal. An evaluation of the restoration in three dimensions and vertical sections were taken (Figs. 7,8,9). The figures showed the CEREC software measuring an actual 5.8 and 6mm post space for 5.5mm post milled. IPS e.max CAD (lithium disilicate glass-ceramic) block was mounted in the milling unit Sirona CEREC 3® compact milling unit (Fig. 3). Each restoration was milled in approximately 15 min using the fast-milling set up (Fig. 11). The milling burs, the cylinder pointed bur and the step bur were changed every 5 cycles to prevent any errors due to bur wear.

Following the milling procedure the restorations were tempered to reach the fully crystallized state. In the course of this process, lithium disilicate crystals ($Li_2Si_2O_5$) are formed to assure optimum material strength (Fig. 10). Groups A and B were scanned, designed, and milled for each die 20 times (Figs.12,13,14). The figures show that the 5mm and 10mm post space measured with the CEREC 4.0® software accurately milled post length of 5mm and 10 mm. Group C die was scanned and milled 20 times. The die for group C was measured up to 13.7. It wasn't able to mill a post beyond 1mm (Fig15,16).

15.0 MEASUREMENT OF PRECISION AND FIT

Each restoration was subjected to a 2 step evaluation to assess the precision of fit. The marginal gap was measured for each Post & Core to determine the fit to the die, using scanning electron microscopy (SEM) technology at the University of Pittsburgh Swanson School of Engineering (Fig. 20). Biological sample condition 10 KV, low vacuum and the backscatter electron compo mode were used. The low vacuum mode was used to prevent charging of the sample. A sample holder stage was created based on the pilot study trial designs (Fig. 21b). The two designs (A and B) were prototyped out of MDF in order to see which was the best way to hold the two surfaces together on the SEM sample stage (Fig 21a). They consisted of stainless steel socket head cap screws and stainless steel springs opposing each other in a yoke. It was determined that a combination of both methods (A and B) worked best, so the MDF prototype model was copied and machined from aluminum with an added base compatible with the SEM sample stage (Fig. 21). Each sample holder stage carried three samples, one from each Group A, B and C, starting from one to twenty (Fig. 22,23).

The interface between the ceramic and the acrylic tooth was measured under 200X magnification. The micrograph was transferred to micrograph analyzing software. The software has a 100 um installed ruler as an analyzing tool to measure the gap (Fig. 24a). Measurement was accomplished using the 100 um installed ruler and a line calibration tool which measure the vertical distance between the margin of the ceramic coping and the die (Fig. 24b). Estimations were done at three points: mesial, buccal and distal for each sample. Three measurement lines were taken at each point. The total was 180 micrographs and nine assessment lines per each sample. Example of micrographs showing smallest interface, medium and largest interface estimated (Fig. 24,25,26)

A total number of 60 radiograph were taken for all samples to determine post length. The machine cone was placed perpendicular to the core and die combination opposing the front side (Fig. 28b). The die was mounted in a block of polyvinyl siloxane heavy body (3M) impression material to mimic the periodontal ligament and bone radio-opacity surrounded by self-curing acrylic resin (Ortho-Jet®) for strength (Fig. 28a). Mipax radiographic software was used to measure the post length from the core base to the end of the post using the ruler tool (Fig. 29). Radiographs for sample number 10 for Group A, B and C are presented in Fig. 29. Examples of the restoration milled for Group A, B and C are demonstrated in Fig. 30. Measurement for each post length was confirmed by using a mm caliper shown in Fig. 31.

16.0 STATISTICAL ANALYSIS

One sample t-tests were used to evaluate actual post length compared to calibrated post lengths. Calibrated post lengths were set to 5, 10 and 14mm. Linear regression was then applied to evaluate the relationship between marginal gap (mesial, buccal, and distal) and post length within each group. One-way ANOVA was adapted to evaluate differences in marginal gap among the three post length groups, with Bonferroni adjustment for pairwise comparisons. Statistical significance was determined to be $p < 0.05$. All analyses were done in Stata 14 (College Station, TX)

17.0 RESULTS

Mean post length for group A, calibrated at 5mm, was 6.3mm. The difference of 1.3 mm was statistically significant ($p<0.01$). Mean post length for group B, calibrated at 10mm was 10.0mm. The difference of <1 mm was not statistically significant ($p=0.75$). Mean post length for group C, calibrated for 14mm, was 11.0mm. The difference of 3 mm was statistically significant ($p<0.01$).

Table 3. One sample T Test Group A

Variable interval	bs	I ean	S td. Err.	S td. Dev	[95 % Conf.
Post length	0	(.3105	.0 844782	. 377798	[6.1 33685 - 6.487315]

Mean=mean(post length) t= 15.5129

Ho: mean = 5 degrees of freedom = 19

Ha: mean < 5 Ha: mean!= 5 Ha: mean > 5

Pr(T < t) = 1.0000 Pr(|T| > |t|) = 0.0000 Pr(T > t) = 0.0000

Table 4. One sample T Test Group B

Variable interval	bs	M ean	S td. Err.	S td. Dev	[95 % Conf.
Post length	0	1 0.0295	.0 900394	.4 026684	[9.8 410 45 - 10.21795]

Mean=mean(post length) t= 0.3276

Ho: mean = 10 degrees of freedom = 19

Ha: mean < 10 Ha: mean != 10 Ha: mean > 10

Pr(T < t) = 0.6266 Pr(|T| > |t|) = 0.7468 Pr(T > t) = 0.3734

Table 5. One sample T Test Group C

Variable interval	bs	M ean	St d. Err.	St d. Dev	[95 % Conf.
Post length	0	1 1.0475	.0 712183	.3 184978	[10. 89844 - 11.19656]

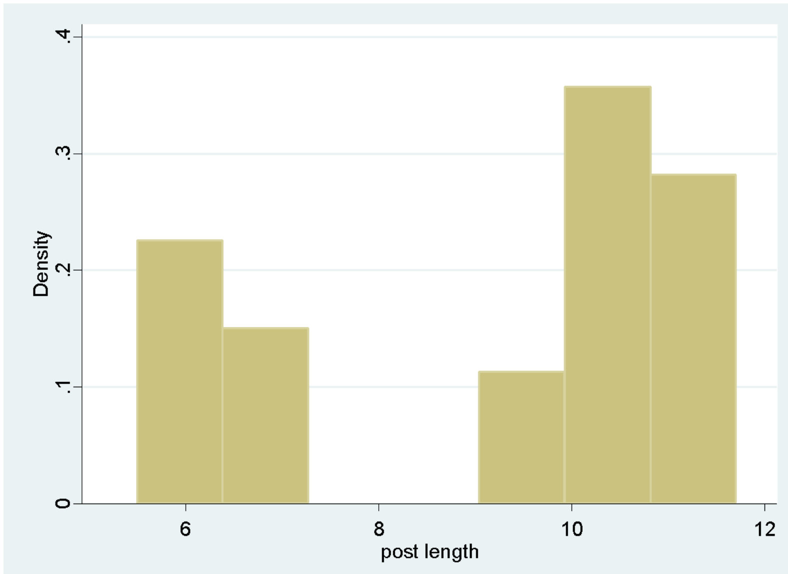
mean = mean(post length) t = -41.4571

Ho: mean = 14 degrees of freedom= 19

Ha: mean < 14 Ha: mean != 14 Ha: mean > 14

Pr(T < t) = 0.0000 Pr(|T| > |t|) = 0.0000 Pr(T > t)=1.0000

Table 6. Histogram Post Length



Overall there was no pattern of relationship between marginal gap and post length among the three groups. ANOVA® showed statistically significant differences in mean mesial marginal gap among the groups ($p<0.01$), with the 5mm post length and 10mm group being significantly different from each other ($p<0.01$). ANOVA® showed statistically significant differences in mean buccal marginal gap among the groups ($p=0.02$), with the 5mm post length group and 10mm group being significantly different from each other ($p=0.01$). ANOVA® showed no statistically significant differences in the distal mean marginal gap among the groups ($p=0.36$). The mean mesial marginal gap for the three groups was 37.85 um, the mean buccal marginal gap was 31.73333 um and the mean distal marginal was 38.16667 um.

Table 7. Histogram showing Mean mesial marginal gap for Groups A,B and C.

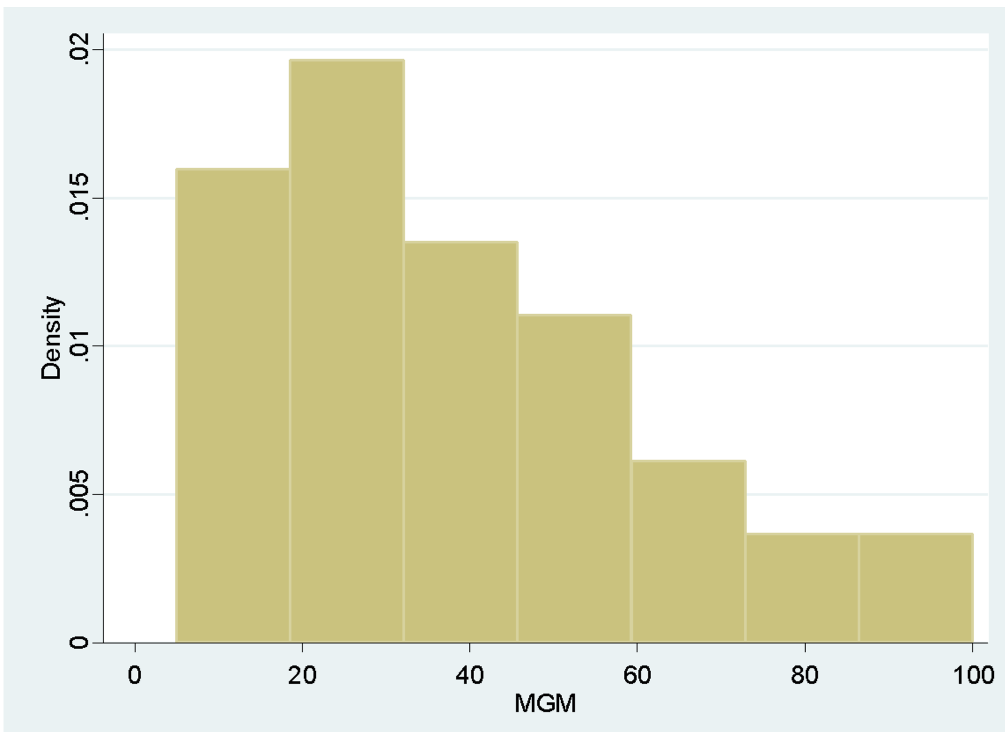


Table 8. Histogram showing Mean Buccal marginal gap for groups A, B and C

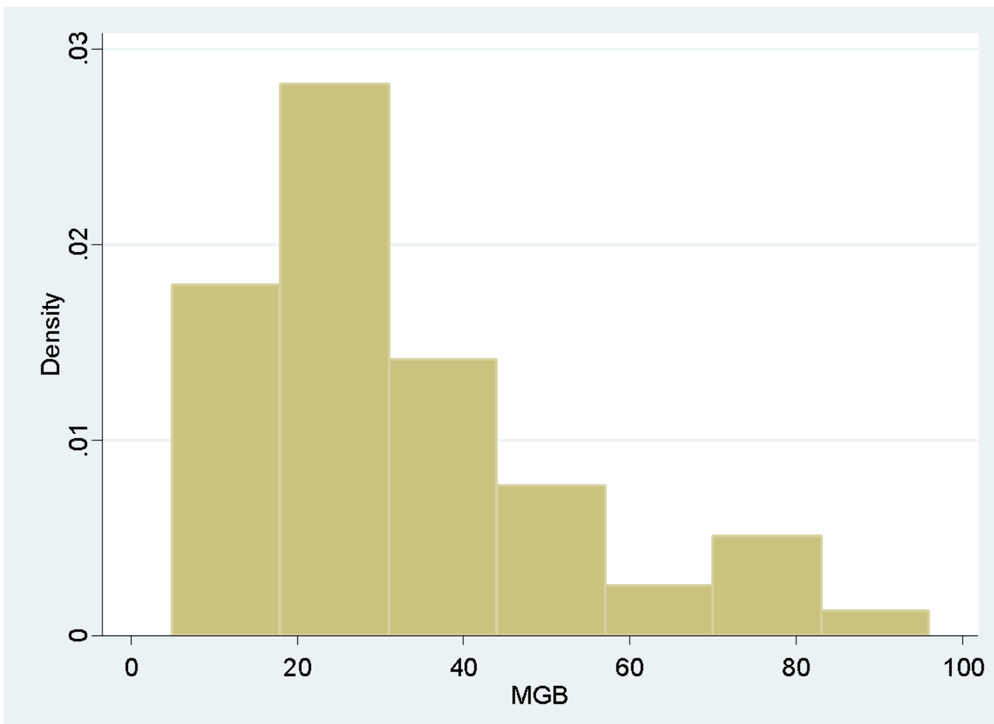
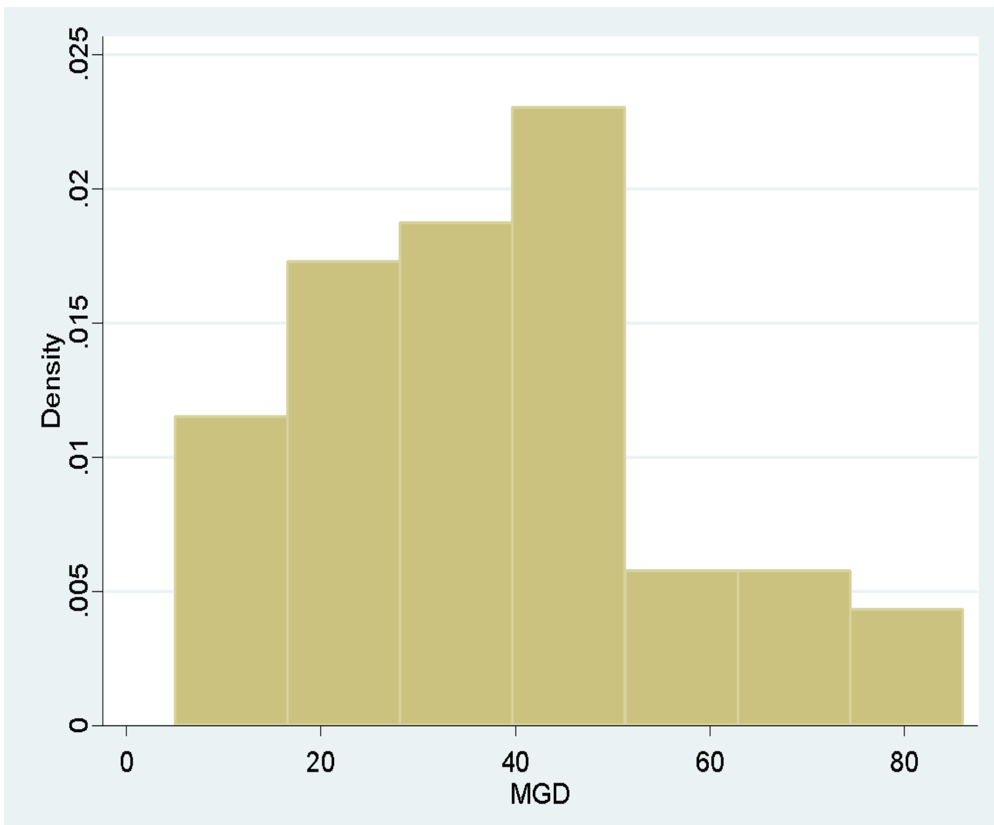


Table 9. Histogram showing Mean distal marginal gap for Groups A, B, and C



18.0 DISCUSSION

The objective of this study was to determine the focal point of the CEREC BlueCam® and evaluate the capability of the machine to mill ceramic Post & Core restorations. Three master dies were fabricated from a polymer material. The coronal part of the die simulated an ideal core preparation (2 mm above the CEJ with a 1.5 to 2mm ferrule). Canal space was prepared to three lengths according to the die group. The canal length of group A was prepared for a post length of 5mm. Group B canal space was prepared for a post length of 10 mm. Group C post length was prepared to 14mm. There are few publications addressing Post & Core restorations. However, a 14mm maximum focal length for the CAD/CAM camera was established through communication with Sirona USA and Sirona Germany[150, 151]. There was only one article in the dental literature concerning this topic[151].

After scanning the restoration 20 times for each group, it was determined that a depth of 5mm and 10mm was relatively easy to reach with the CEREC three camera. A 13.7mm depth was captured by the camera at the 14mm depth. However, the machine wasn't able to mill any restoration beyond 11mm. The Mean post length for Group A was 6.3mm, which was longer than the prepared post length. The difference of 1.3mm was statistically significant ($p<0.01$). Mean post length for Group B was 10.0mm, which is the same length of the prepared post space.

The difference of <1mm was not statistically significant ($p=0.75$). The mean post length for Group C was 11.0mm, which was three mm shorter than the prepared post space. The difference of 3mm was statistically significant ($p<0.01$).

In a pilot study, die D was prepared and scanned as in group A,B and C above, with the post space depth prepared to 15mm. The die was scanned with the camera, and a virtual model was created. The camera could not read at the 15mm depth. The proposed model was missing the final working depth point. The software offered a restoration with no post at all Instead it had a hole similar to the virtual model (Fig. 17). The model was milled, and a core with a hole and without a post was the product (Fig. 18).

During the pilot study three restoration spacer parameters were tried 0, 10 um, and 20 um. Samples of six restorations were fabricated using the Lava® ultimate Cad/Cam restorative blocks, three for each die at 5mm and 10mm in depth. It was noted that the post length was 1 mm shorter after changing the space parameter from twenty to zero um. However, delivery of the milled Post & Core was less passive. Several adjustments were performed in order to insert the restoration with a minimum marginal gap. Nakamura et al., determined that the marginal fit of CEREC crowns were changed when the cement space was altered from 10 um to 30-50 um. The marginal gap with space setting 30-50um ranged from 53-67 um. Nevertheless, the space setting of 10 um showed a gap of 95 um[158]. This study had different findings from Nakamura study. This could be due to the difference in the restoration type. Nakamura study was carried out on CEREC crowns. This study of Post & Core restorations was considerably different. It was determined in this study that the CEREC software considers the post as a part of the internal surface of the restoration. When the space parameter is changed, the software increases the relief of the inner face of the post. This is the reason why the post length is shortened. The longest posts were milled at zero space parameters. The posts were engaging the canal and were not passively seated without significant adjustments. Posts milled at the 20-um setting were 1mm shorter and passively seated. In conclusion, the 10 um calibration was chosen as the ideal space setting for Post & Core. This setting balances post length and the passive fit of the restoration. It was found that minimum adjustments were needed at this setting.

Overall, there was no pattern of relationship between marginal gap and post length among the three groups. ANOVA® showed statistically significant differences in mean mesial marginal gap among the groups ($p<0.01$), with the 5mm post length group and 10mm group being significantly different from each other ($p<0.01$). The test also showed statistically significant differences in mean buccal marginal gap among the groups ($p=0.02$), with the 5mm post length group and 10mm group being significantly different from each other ($p=0.01$).

The results agree with ADA specification No. 8[128] which states that the luting cement for a dental crown should not surmount 40 um when using type II luting agent. Christenson's study agreed as well with the ADA specification and our results[130]. Another Scanning electron microscopic study by Lofstrom LH et al., on cemented cast gold restorations showed that margins from 7 to 65 um were acceptable[146]. Multiple in vitro studies found the mean marginal gaps ranging from 9 to 82 um which agreed with this investigation[139, 140, 141, 142, 143].

The present study had limitations using the Sirona CEREC SW BlueCam® and the Sirona CEREC Three Compact Milling Machine®. Currently the most predominant CEREC system is its fourth generation product, CEREC AC BlueCam®. It captures images using a visible blue light emitted from an LED blue diode as its light source. The CEREC AC BlueCam® can capture one quadrant of the digital impression within 1 minute and the antagonist in a few seconds. The newest CEREC system, CEREC AC Omnicam®, marketed in 2012 offers higher qualities. First, BlueCam® imaging is a single-image acquisition technique, while Omnicam® imaging technology is a continuous imaging mode. With the latter method, serial data acquisition generates a 3D model. The BlueCam® can be applied to a single tooth or to a quadrant. The Omnicam® can be used for a single tooth, quadrant or an entire arch. Finally, BlueCam® must be used with an opaque powder coating of titanium dioxide before scanning to assure uniform light dispersion and to improve scan efficacy[83]. Advantages of the Omnicam® over the BluCam® include powder-free scanning and precise 3D images with natural color. Powder-free scanning has a superior advantage with a larger scanning area[84]. It is possible that introduction of the Optispray® powder to 14mm post length might introduced errors in capturing the full depth of the prepared canal. Accumulation of the powder at the end of the canal working length could have been the reason behind the milled post being shorter than the actual canal length. The virtual model created by the software was able to detect a depth up to 13.7mm, but the milled post only extended to 11mm. Use of the new Omnicam® technology could resolve errors introduced by the Optispray® powder.

This study presents a new valid method of fabricating custom made ceramic Post & Core. A post length up to 11mm was successfully milled which is an adequate depth for a post space. According to Torabinjad [47] about 5mm or more of radiographic gutta percha is necessary to assure an apical seal [47,48,49]. For the anteriors and bicuspid teeth it is recommended that 5mm of apical gutta-percha be retained, and the post extends to that level. However, for molars the length is determined by the root thinning or perforation. Posts in molars should be extended approximately 5 mm in the canal length[47,50]. While measuring 700 teeth, Shillingburg et al., noted that making the post length equal to the clinical crown length would cause the post to encroach on the 4.0mm "safety zone" of gutta percha in some teeth[51]. Zillich and Corcoran presented data comparing length guidelines to average, long and short root lengths and the need to retain adequate apical seal. When posts were one half of the root length, the endodontic seal (5 mm) was rarely compromised in average roots. When posts were two-thirds of the root length, many of the average and short root length teeth had compromised apical seals. When the post was equal to the crown length, an adequate seal was only possible on teeth with average or long root lengths. With short-rooted teeth, even the shorter post guideline of being equal to the crown length produced a compromised apical seal.

High strength ceramic Post & Core systems allow for the fabrication of restorations with optimal esthetics, good biocompatibility and an excellent periodontal tissue response. In addition, bonded restorations have higher resistance to vertical root fracture. Bex et al.,[17] investigated the effect of dentin-bonded resin post-core preparations on resistance to vertical root fracture and concluded that dentin-bonded resin post-core restorations provided significantly less resistance to failure than cemented custom cast Post & Core and that the dentin-bonded resin Posts & Core fractured in every instance before the roots fractured. Saupe et al.,[18] compared the fracture resistance between custom metal cast Posts & Core and a resin-reinforced dowel system for structurally compromised roots. Their results indicated that resistance to the masticatory load of a resin-reinforced Post & Core system was greater than that of a morphologic Post & Core restoration. They also reported that when a bonded resin Post & Core was used on structurally weakened roots, there was no statistically significant difference in strength between Post & Core restorations that used a ferrule and those without a ferrule.

Having the Post & Core in a single unit decreases the frequency of failure by creating a monoblock, which has various advantages over its multiple unit counterparts.

Digital dentistry offers optimum dental service in the same visit, saving both patient and clinician time and money. Fasbinder et al.,[19] has shown that the use of digital impressions is more efficient than the usual 5-7-minute set times of polyvinyl-siloxane impressions. One recent study reported that scanning was 10 minutes faster than conventional impressions for single abutments and short span fixed partial dentures[19,20].

Future studies

With the availability of newer CAD/CAM systems the Omnicam® and with future new generations of the system more research is needed to evaluate the impact of this recent technology on the Post & Core method proposed in this study. Further evaluation of the biomechanics of high strength ceramics and zirconia in terms of their shear and fracture strength, fatigue and cyclic load when used as Post & Core is suggested since dental literature lacks detailed information in this venue. The resin bond strength between ceramics and dentin, and its effect on the post tooth combo needs to be evaluated as an altering factor for the fracture behavior of these posts. Bond strength testing methods are proposed, like macroshear and the macro-tensile bond strength test. Finally, clinical trials and long-term follow-up are recommended, as these in vitro studies have limitations.

19.0 CONCLUSION

This study evaluated the use of CAD/CAM technology as a method to fabricate single-unit all-ceramic Post & Core restorations by means of a direct optoelectronic scanning impression of the post space and milling of the ceramic Post & Core restoration. The results of this study disprove the null hypothesis:

1. Chair side CAD/CAM technology (Sirona CEREC BlueCam®) cannot produce direct single unit all ceramic Post & Core restorations with an canal depth of 10 mm. Results prove that chairside CAD/CAM technology (Sirona CEREC BlueCam®) can produce direct single unit all ceramic Post & Core restoration up to 10mm of canal depth .

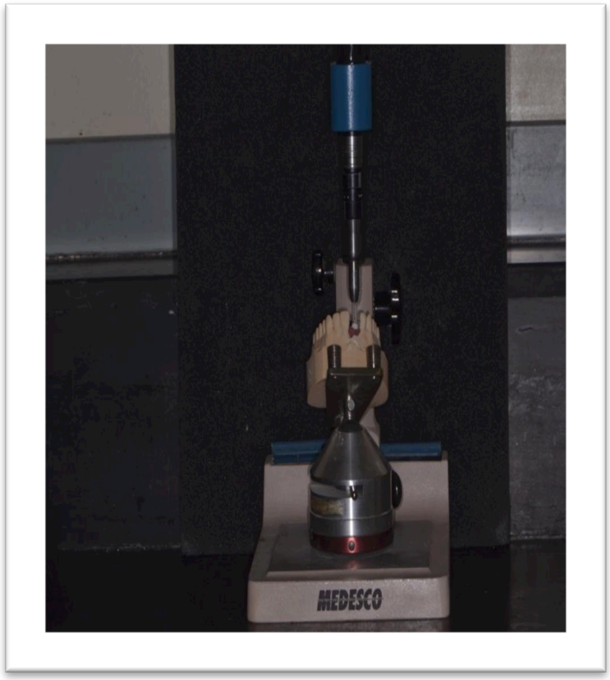
2. There was no pattern of relationship between marginal gap and post length among the three post groups. The Mean marginal gap for the three groups was 38 um. The smallest detected gap was 5 um and the largest 100 um. The present study marginal gap results according to Holmes definition are clinically acceptable.

3. Chairside CAD/CAM is a valid method for fabricating a single unit all ceramic Post & Core.

Future studies are needed to evaluate the biomechanical properties of ceramic Post & Core restorations

20.0 FIGURES

Figure 1. Scannable model made from whip mix lean rock stone®



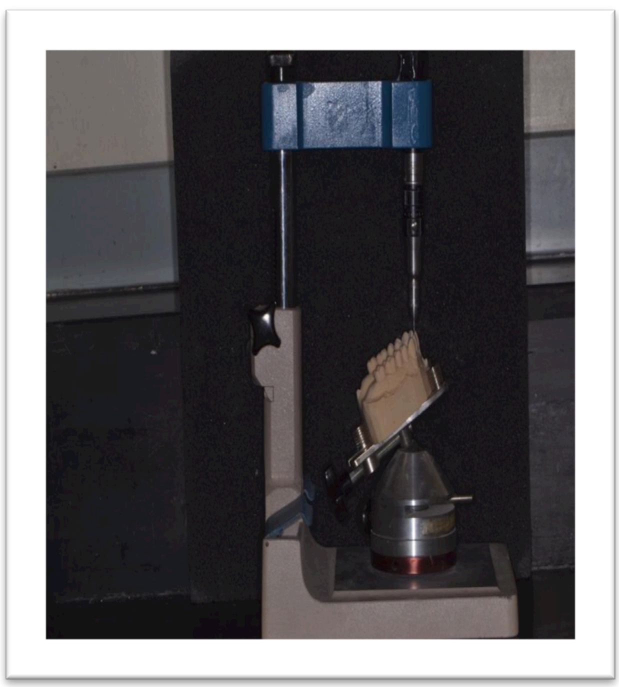


Figure 2a and b. Handpiece surveyor was used to idealize the preparation depth.

Figure 3. Sirona CEREC SW bluecam® and compact milling machine.

Figure 4. Sirona CEREC BlueCam® software

Figure 5. Sirona CEREC BlueCam® software

optoelectronic scanning of post space

Figure 6. Restoration parameter was set at 10 um for the spacer for all groups respectively.

Fig 7) 5.8 mm post space and post restoration measured with 4.0 Cerec ® software

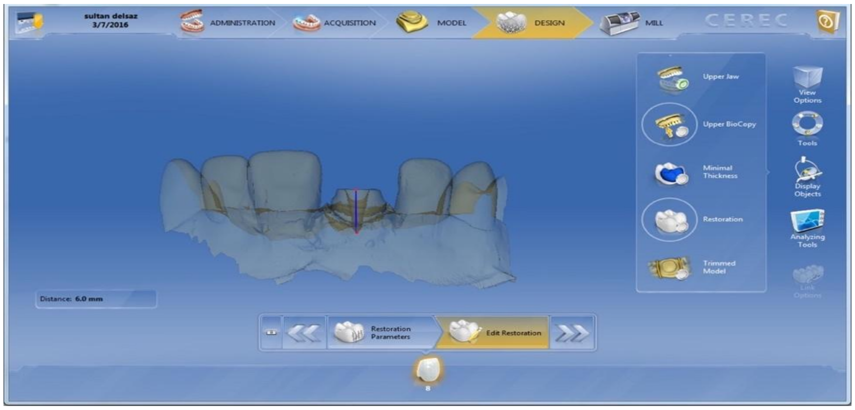


Figure 8. 6mm post space measured with CEREC® software 4.0

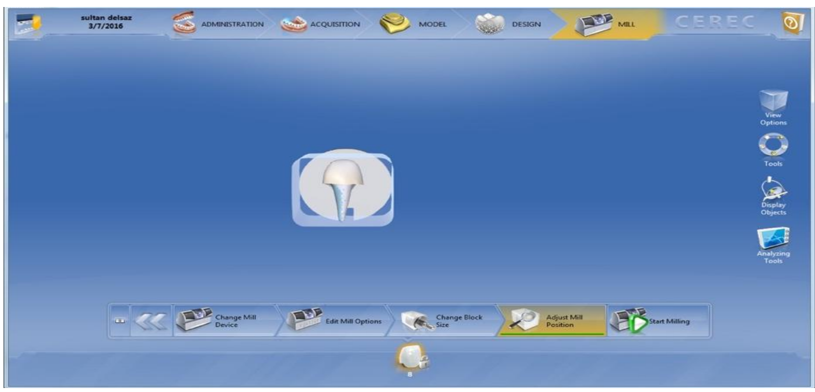


Figure 9a. Front view pre milling 5mm post

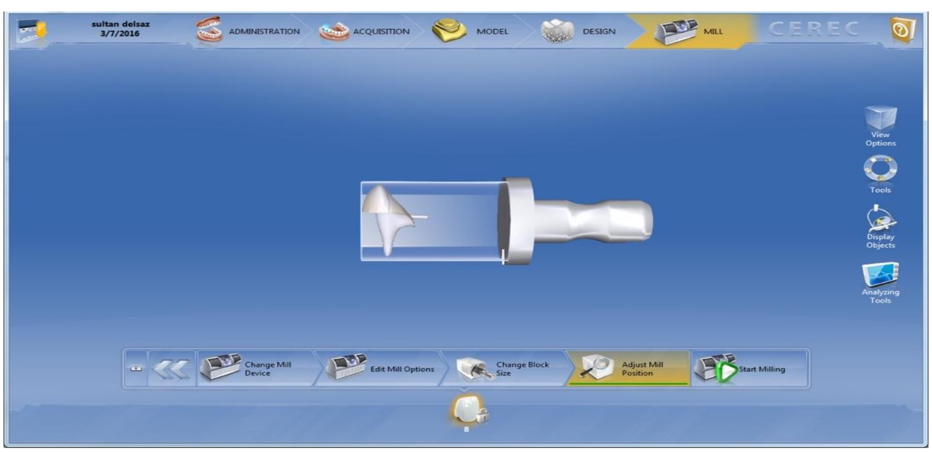


Figure 9b. Side view pre milling 5mm post

Figure 10. Ceramic firing furnace

Figure 11. Compact milling machine fabricating the post

Figure 12. 10mm post space and proposed Post & Core

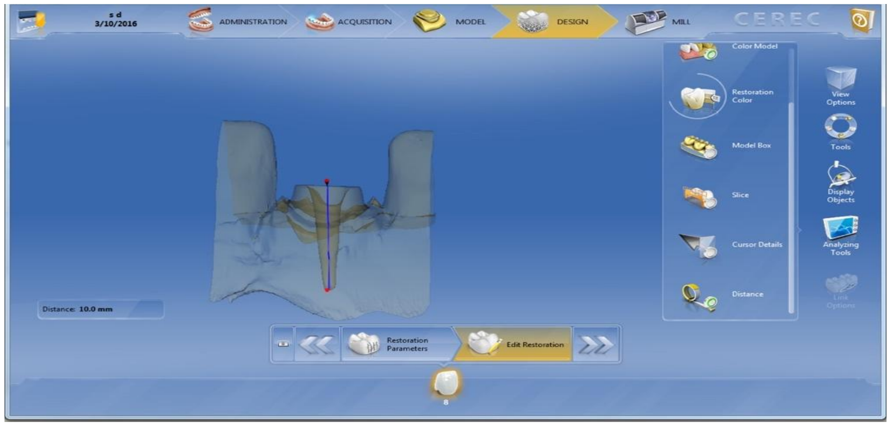


Figure 13. 10mm post space depth measured with 4.0 CEREC® software

Figure 14a. pre-milling proposal for 10mm Post & Core

Figure 14b. Side view pre milling proposal for 10mm Post & Core

Figure 15a. Group C post space 14mm proposed and core 11mm

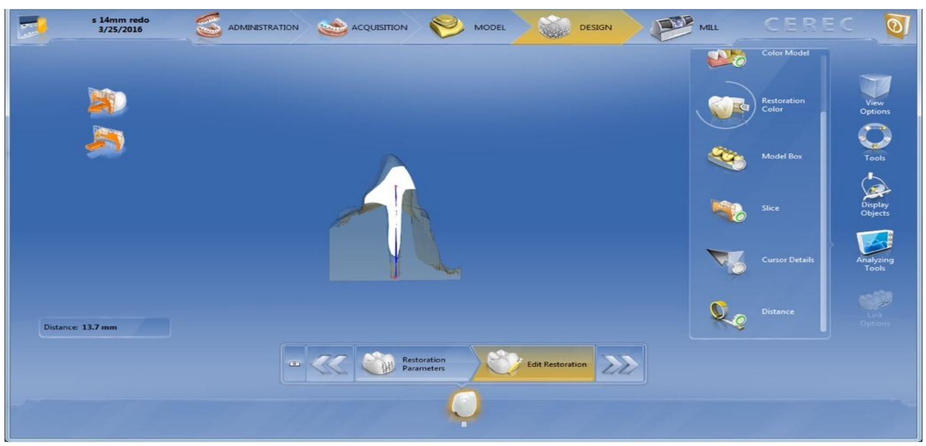


Figure 15b. Group C post space measured with the software 13.7, however the proposed restoration shown is only 11mm

Figure 16a. Group C 11mm post front view pre milling proposal

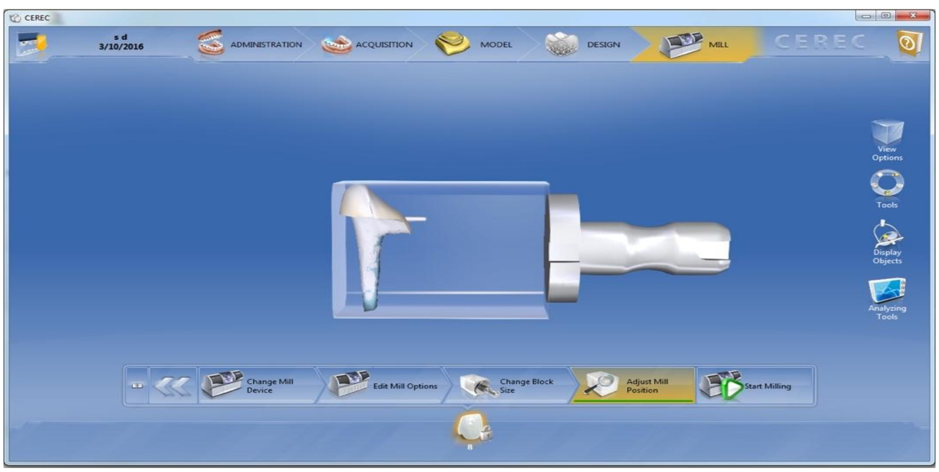


Fig. 16b. Group C 11mm post side view pre milling proposal

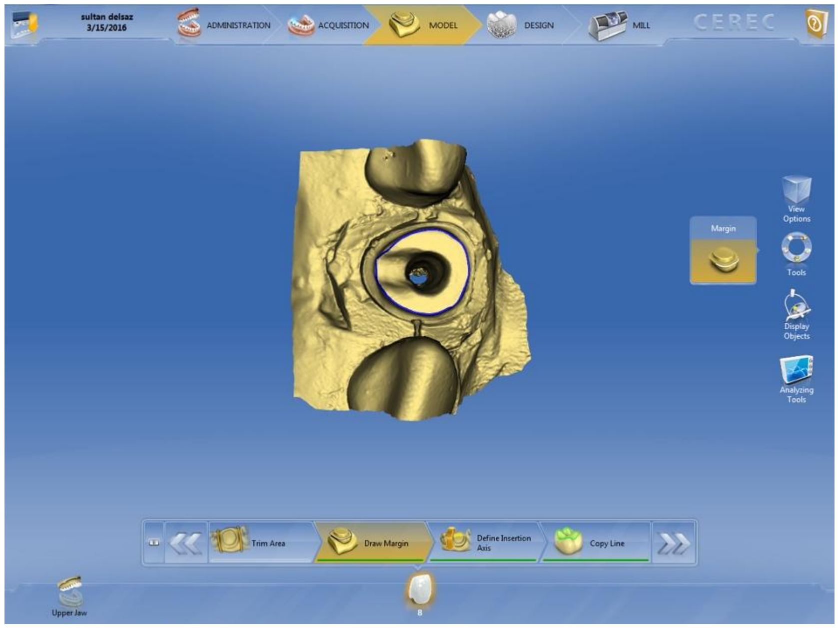


Figure 17. Camera wasn't able to read the end working length point

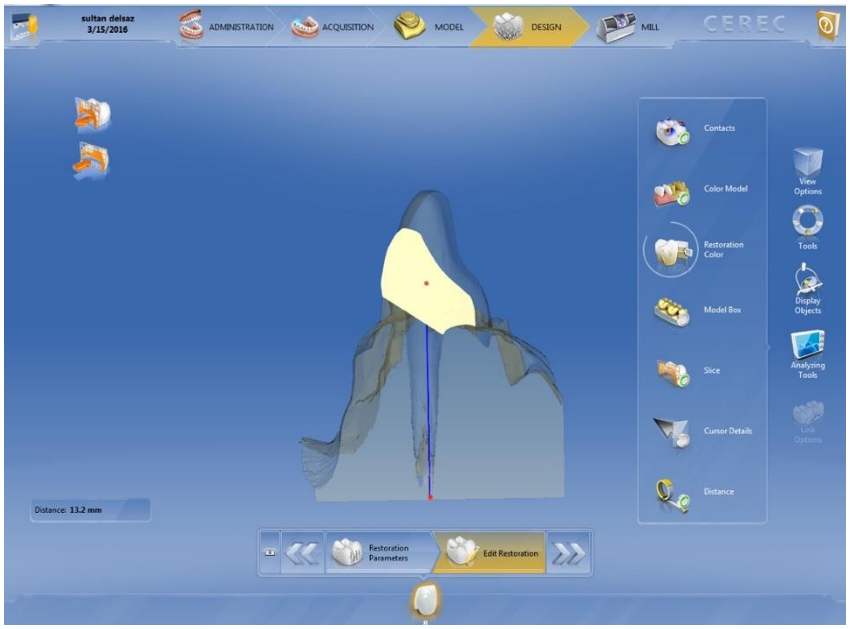


Figure 18a. Software proposing a restoration of the core side view only.

Fig. 18b. Software proposing a restoration of the core front view only.

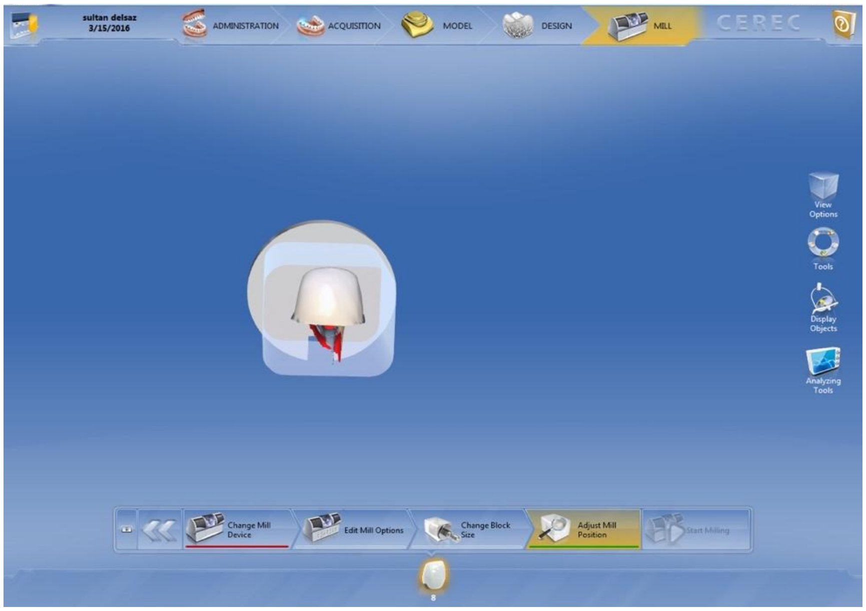


Figure 19a. Milling proposal of the core front view only.

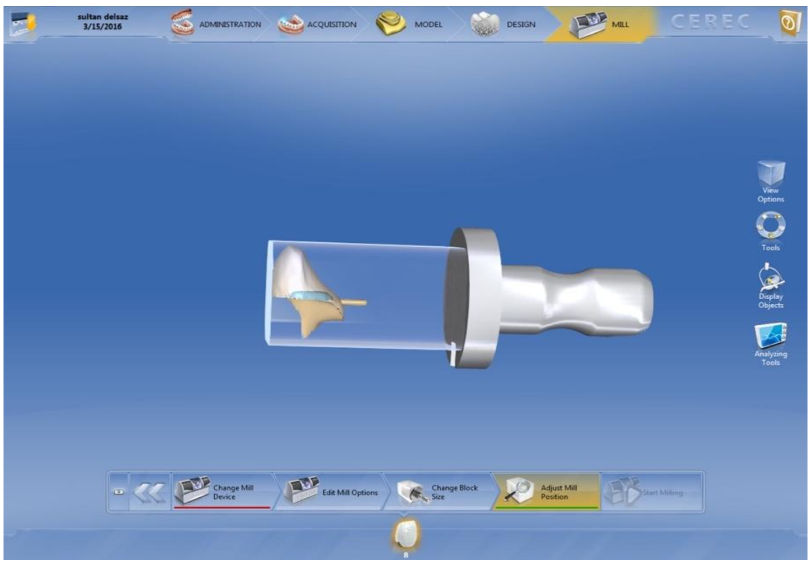


Figure 19b. Milling proposal of the core front view only.

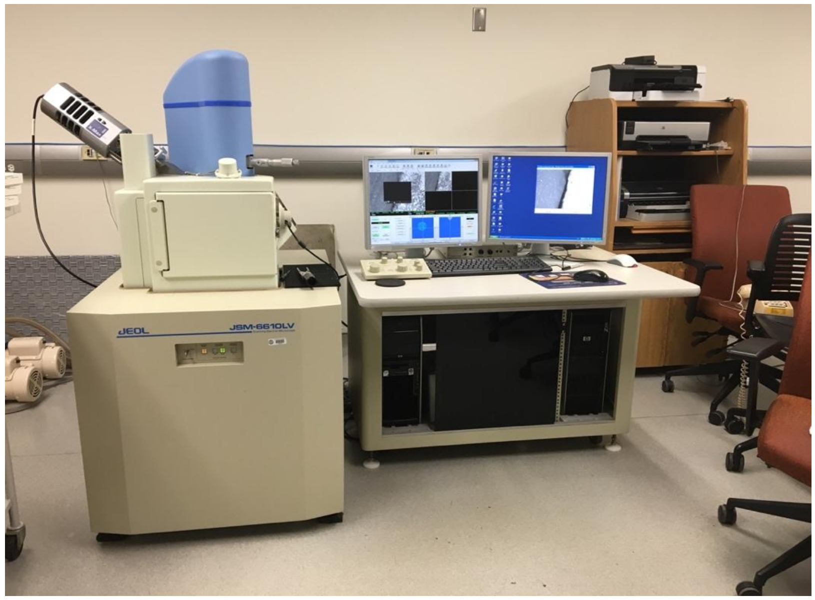


Figure 20a. JSM -6610LV® scanning electron microscope

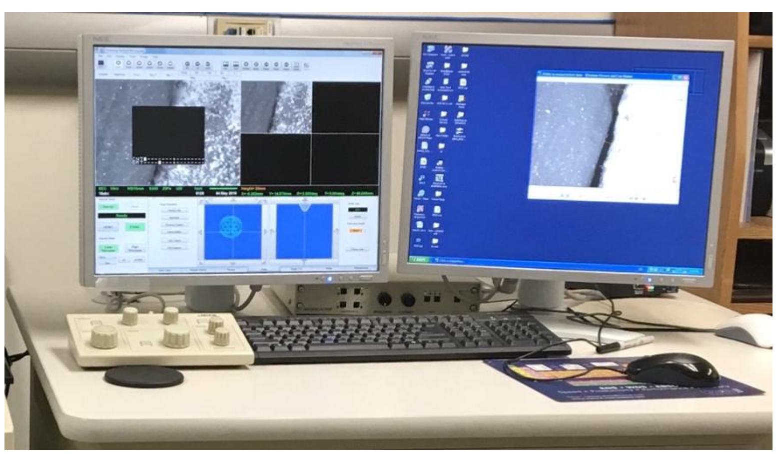
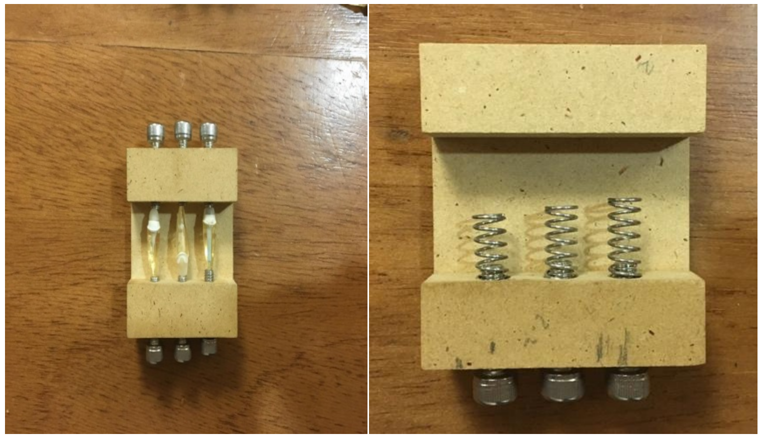


Figure 20b. Marginal gap micrograph process using the software



design A design B

Figure 21a. Sample holder stage

Figure 21b. Aluminum mechanical device for holding samples

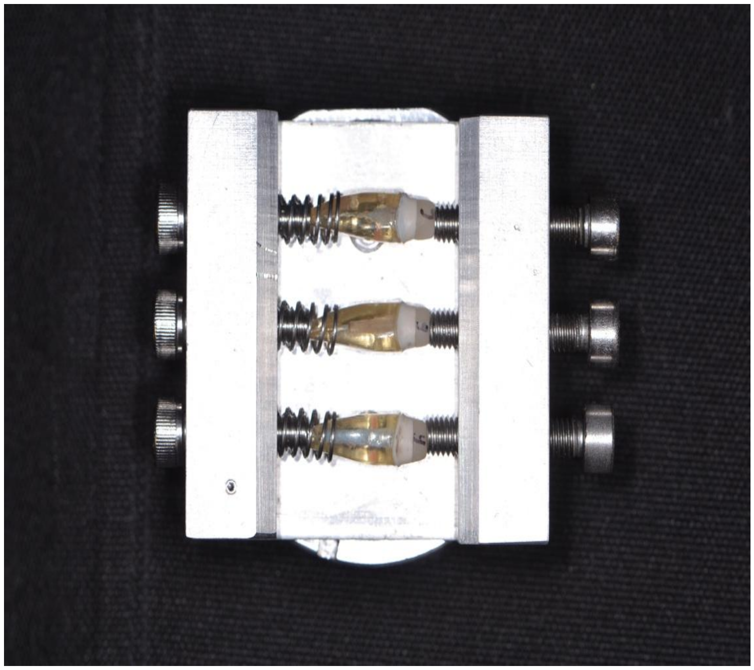


Figure 22. The three groups sample mounted A on the far right and C on the far left

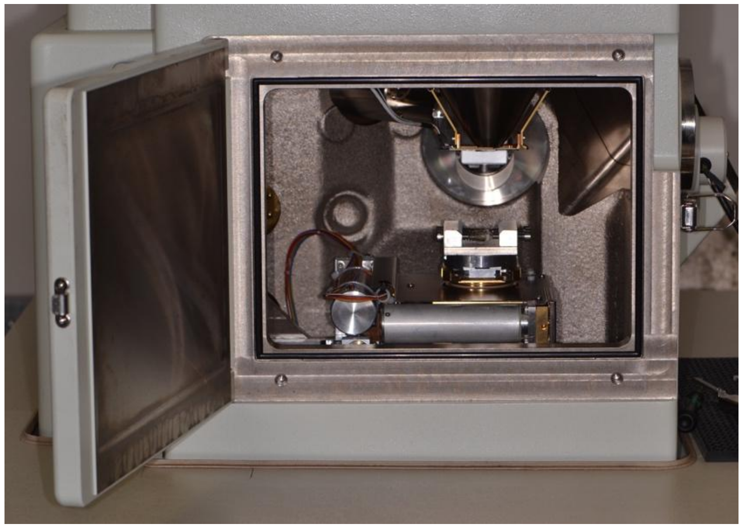


Figure 23a. Sample inside SEM chamber

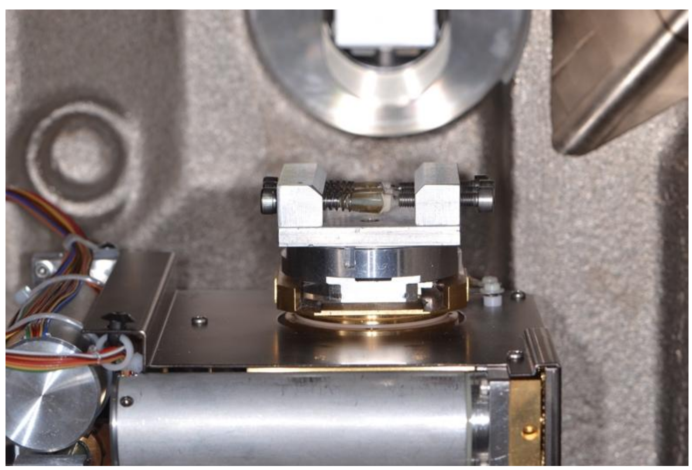


Fig. 23b. Mounted sample inside SEM chamber

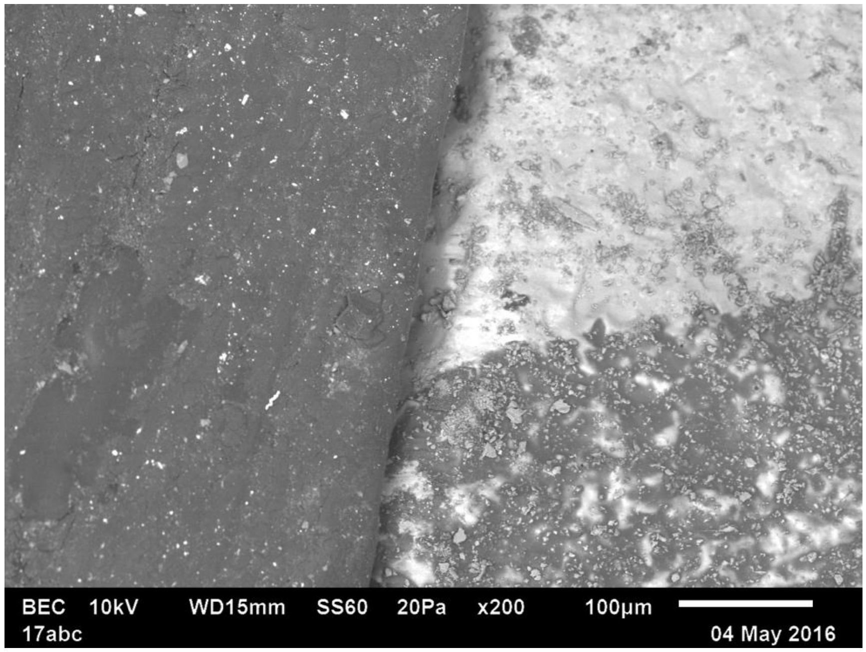


Figure 24a. Sample 17 Group c mesial point measurement at X200.

Picture showing the 100 um ruler.

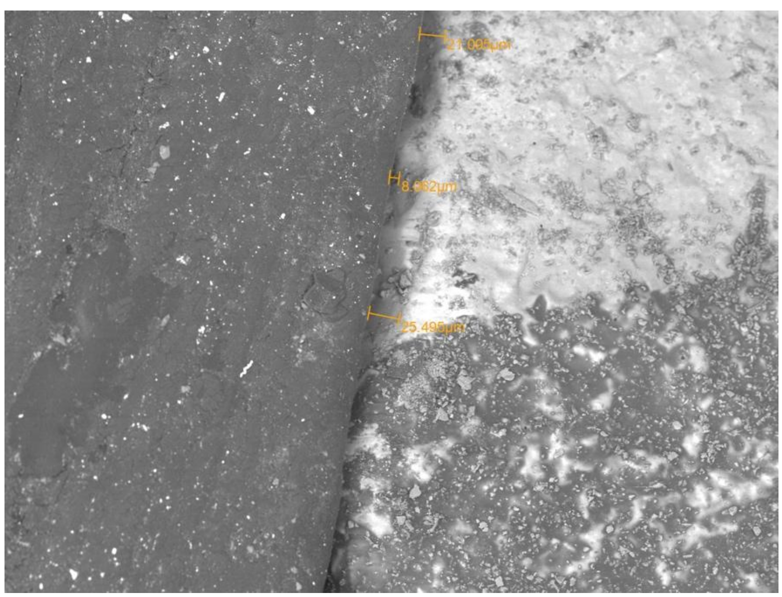


Figure 24b. Sample 17 Group C mesial point measurement using the line measurement tool at three areas.

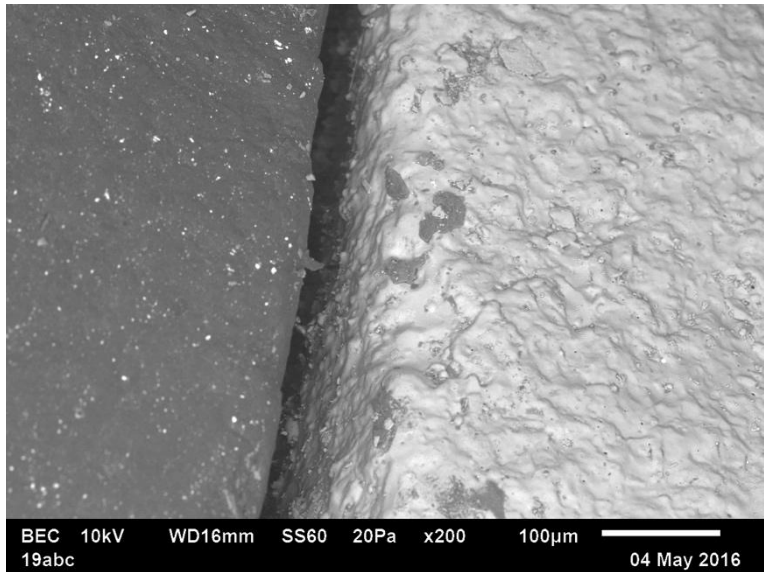


Figure 25a. Sample 19 Group C buccal point measurement

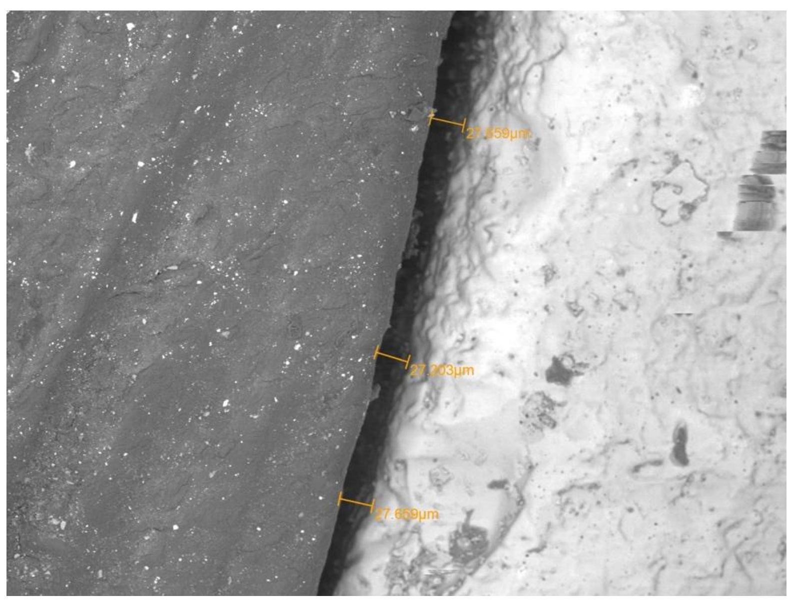


Figure 25b. Sample 19 Group C buccal point measurement, using the line calibration tool at three areas

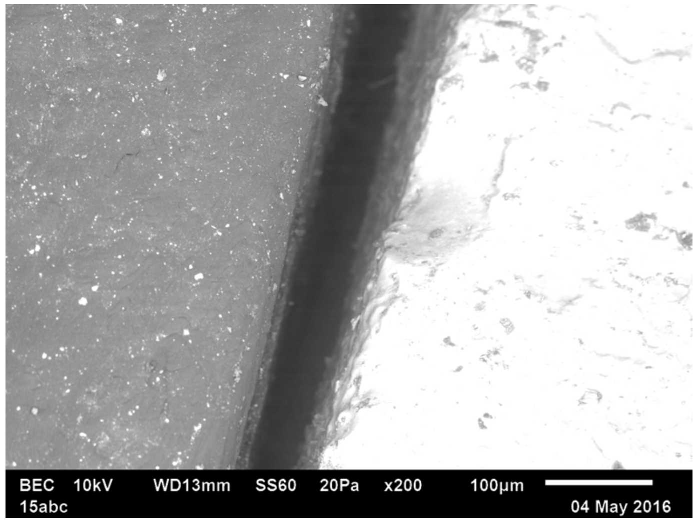


Figure 26. Sample 15 Group B mesial point

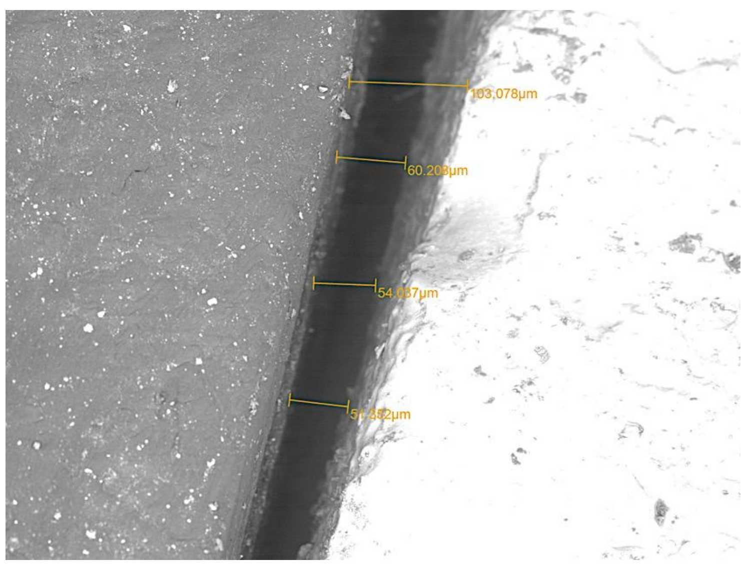


Figure 27 Sample 15 Group B mesial point

Figure28a. The die was mounted in a block of polyvinyl siloxane heavy body (3M) impression material surrounded by self-curing acrylic resin (Ortho-jet).

Figure 28b. The x-ray machine cone was placed perpendicular to the core and die combination opposing the front side.

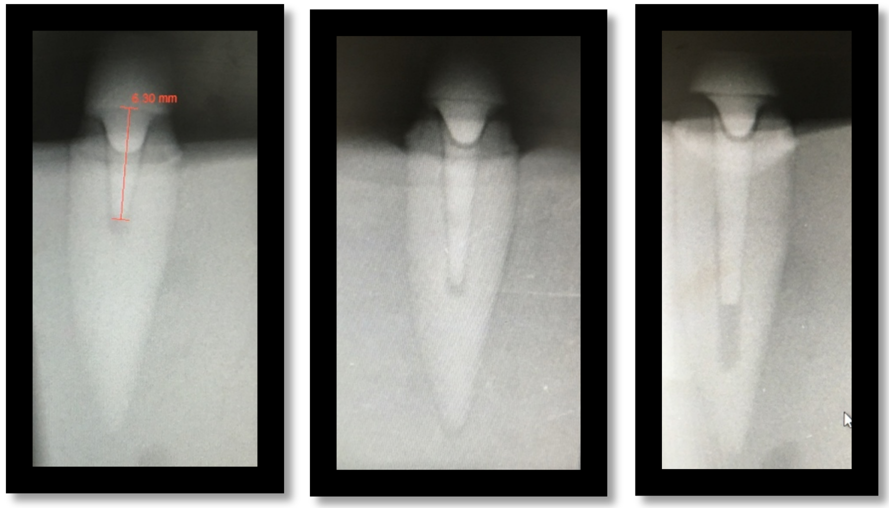


Figure 29. Mipax® x-ray software

Radiographs for sample number 10 for Group A, B and C

Figure 30. Examples of the restoration milled for Group A, B and C

Figure 31. mm caliper

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